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A review of the effect of alcohol hangover on attention and memory

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Abstract. Alcohol hangover (AH) refers to adverse mental and physical symptoms after a heavy consumption of alcoholic drinks, which had a significant effect on socioeconomic development and drew a huge amount of interest among psychologists in recent years. Studies found that AH mainly affected people's cognitive performances, especially memory and attention functioning, while the findings in this field were controversial. This paper aimed to review the articles and examine the effects of AH on attention and memory by focusing on their cognitive subdomains and different study designs to find explanations for their inconsistent results. The review article showed that among attention functioning, psychologists found consistent damaging effects of AH on selective attention and sustained attention behaviors whereas the effects of divided attention performance were inconsistent. Moreover, insufficient attentional resources were regarded as the mechanism of divided attention deficit during the AH state. Among studies of memory functioning, the encoding phase was believed to be a significant factor for impaired retrospective memory performance during the AH state compared with the retrieval phase, while the effect of the memory retrieval process was not clearly tested during AH. In addition, the AH state also negatively affected the prospective memory ability to implement behaviors at a specific future time or place. The distinct study methodologies (laboratory vs. naturalistic studies; within-subject vs. between-subject design; student vs. non-student sample) were suggested to be the contributors to these conflicting results.

Keywords: Alcohol Hangover, Attention, Memory.

1. Introduction

The alcohol hangover (AH) is characterized as a common after-effect of an episode of heavy alcohol consumption (e.g. for women who drink exceed four alcoholic drinks and for men who drink exceed five alcoholic drinks) with combined physical and mental symptoms involving fatigue, headache, nausea, and anxiety, which may present simultaneously or sequentially [1, 2]. The symptoms of AH typically present 6 to 8 hours after heavy drinking, which starts when the person's blood alcohol concentration (BAC) approaches zero [1]. Recently, AH has been added as a single entity in the International Classification of Diseases (ICD-11), differing from acute intoxication [3]. Current researches showed that cognitive deficit was one of the most obvious AH symptoms including psychomotor speed, short-term memory, long-term memory, and sustained attention [4]. These impaired cognitive functions also led to significant socioeconomic losses in many developed countries due to reduced productivity or

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absenteeism among employees [5]. However, the findings about the effects of AH on cognitive functioning (especially attention and memory performance) were inconsistent. Therefore, it is essential to review the effects of AH on attention and memory functions targeting at their separated subdomains and distinct study designs, which may provide some insights into the explanation of these controversial findings and understanding of the difficulties suffered by people who had AH.

2. Definitions and main methodologies

2.1. Definition of attention

Attention refers to a consciousness when people can only focus on either a single stimulus or multiple stimuli, which can be divided into three main subgroups: selective attention, sustained attention, and divided attention [6]. In terms of selective attention, it refers to the ability to respond to only one specific stimulus, avoiding other irrelevant stimuli (distraction). It was always tested by the Stroop task (only focusing on and naming the ink color of color words) and the Flanker task (only responding to the central target and ignoring the irrelevant stimuli around) [7]. Sustained attention refers to the ability to keep attention over a continuous period, which was measured by vigilance tasks (recognizing the emergence of infrequently appeared stimuli) [7]. Divided attention is about the ability to simultaneously respond to multiple stimuli, which could be measured by tasks either using the same modality(e.g. spatial modality) or involving different modalities(e.g. a dual-paradigm- verbal modality combining with spatial modality) [7].

2.2. Definition of memory

Memory refers to a process of encoding, storing, and retrieving information, which could be divided into two main subgroups: short-term memory and long-term memory. Content in short-term memory could be stored for a short time (several minutes) and it needs repeated rehearsals to be stored as a long-time memory. However, in terms of long-term memory, the information stored could be retrieved across time from minutes to years [7]. In addition, long-term memory was further separated into retrospective memory (retrieval of past information) and prospective memory (ability to conduct the planned behaviour in a predetermined time period) [8]. Ayre et al. indicated that attention is related to memory as attentional resources are involved in efficient memory functioning [5].

2.3. Main methodologies in alcohol hangover studies

Two main research designs were used in the study about the effect of alcohol hangover: laboratory studies and naturalistic studies. The laboratory studies typically recruited two groups of people in which one group was given a dose of alcohol based on their body weight and the other group was given a cup of non-alcohol drink. The drinking time and alcohol type were strictly controlled. Participants took part in trials held in the lab when the acute alcohol intoxication effects disappeared, which was verified by the estimated blood alcohol level (BAL) approaching zero [7]. However, for the naturalistic studies, they recruited natural hangover subjects to participate in tasks in the morning after a drinking night while the drinking time and alcohol type were not controlled [7].

3. Effect of alcohol hangover on attention

Recently, researchers have shifted the focus from laboratory hangover studies to naturalistic hangover studies as a part of participants in naturalistic studies reported a higher amount of alcohol consumption beyond the ethically permissible amount in laboratory studies. These naturalistic studies suggested consistent results of the detrimental effect of AH on selective attention, whereas the results on divided attention were inconsistent, which could be due to several methodological differences between the studies. The same group of experimenters conducted two naturalistic studies that went through a similar batter of attention tasks after an alcohol hangover using distinct types of samples. Devenney, Coyle, and Verster examined the effect of AH on attention in a student sample using a between-subject design [9]. The results suggested that student participants in the AH condition only showed deficits in selective

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attention reflected by significantly longer interference time in both the Flanker task and the Stroop task compared with that in the alcohol-free condition, while their divided attention performance remained intact. However, when they recruited a non-student sample using a within-subject design, the results suggested both selective attention and divided attention performance were badly affected [10]. Even though the age of subjects recruited in the second study was not reported, the age of social drinkers might be higher than that of students, which could be a confounding variable leading to worse performance in attention compared with student samples. Besides, based on the distinct designs(between-subject design vs. within-subject design) used in these two investigations, study design may also contribute to the different results. For the first study, individual variability in between-subject design may mask the difference of divided attention between two conditions when the sample size is not large enough. However, for within-subject design, the order effect could interfere with the results as people may have better performance in the second test. In addition to field naturalistic study, a field and internet mixed naturalistic study indicated that internet naturalistic study was as effective as field naturalistic study [11]. The experimenters recruited the subjects on a street and invited a part of the participants to attend to an online cognitive task while another part of the participants attended the field study the next morning after a typical night out. The results found that there was no significant difference between the two groups. Thus, this internet naturalistic methodology would be effective for researchers to a get large sample size in a short time as well as gain valid data even during special periods such as during COVID-19.

In addition, some researchers explored the mechanism of impaired divided attention during AH. Ayre et al. applied a dual-attention semi-naturalistic paradigm on social drinkers using a within-subject design to test their divided attention performance [5]. For both AH and control groups, participants completed two sessions: single condition and divided attention condition. In the single condition, subjects were informed to only attend to simple words heard through headphones, while in the divided attention condition, they were asked to track a moving dot using a mouse and listen to the simple words simultaneously. The attentional load was manipulated by defining the divided attention condition as the attentional high load condition and defining the single condition as the attentional low load condition. The study showed that in the divided attention condition (attentional high load), participants in the AH group had impaired performance in the tracking task compared with that in the control group, which suggested that the depleted attentional resource could be a factor of divided attention deficit. Moreover, subjects in the AH group had significantly worse performance in the word recognition task than that in the control group, independent of attentional load (single condition vs. divided attention condition). These results indicated that AH state did not affect people's attentional resource capacity but it influenced the allocation processes of attentional resources, leading to depleted attentional resources in each of the two competing tasks [5]. The researchers also suggested that people might only have impaired divided attention performance in different modalities (e.g. visual and auditory dual tasks) that had large attentional demands [5]. However, for the divided attention tasks in the same modality (e.g. visual divided attention tasks), their attentional requirement was too small to find a significant impairment for people in the AH state. Therefore, the attention tasks divided across distinct modalities might be suitable paradigms to assess the divided attention performance during AH.

4. Effect of alcohol hangover on memory

Previous studies suggested that the memory encoding phase had a significant influence on impaired performance in long-term memory and short-term memory occurred after an alcohol hangover. For instance, Howland et al. showed that when the encoding phase happened before the alcohol hangover period, participants did not exhibit any memory deficits [12]. They conducted a double-blind experiment using a within-subject design to examine whether short-term memory would be affected if participants encoded the information before they drank, which was measured by a quiz related to the video lecture presented the day before measurement when they were sober. The results indicated that when participants encoded the information before AH, their short-term memory performances during AH were as intact as those of non-hangover situations. However, when both memory encoding and retrieval

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phases happened during AH, short-term memory and long-term memory were severely impacted. McKinney and Coyle also applied a within-subject design but used a naturalistic study to measure their memory performance reflected by the verbal recall and recognition score when subjects were tested the next morning [13]. They found that people in the AH condition were less accurate at word recognition and recall compared with those in the non-hangover condition, which suggested impaired memory performance during AH. Even though the findings of these two studies might collectively suggest that the encoding phase affects memory ability more during AH than that of retrieval, the importance of the retrieval phase could not be denied as no study has tested it. Therefore, a study that tests participants' memory performance when they encode the information during AH but retrieve it in a sober state is needed to examine the effect of memory retrieval during AH.

Apart from the effect of AH on retrospective memory, experimenters also found that AH had a significant negative influence on prospective memory (PM) performance [14]. The Prospective Remembering Video Procedure (PRVP) paradigm was applied to test the PM ability in AH participants [8]. The PRVP is a laboratory-based task that includes 12 location-action combinations. The participants were asked to watch a 10-min video about a shopping center including passengers and stores featured with their names. These 12 combinations were introduced before they watched the video. When participants watched the video, they were asked to write down each combination only when the location/store mentioned in that combination appeared in the video and they were forbidden to write it down before the location/store presented. In this task, people in the AH condition had significantly lower PRVP scores than those in the non-AH condition, which indicated that prospective memory was affected during AH [14].

5. Discussion and suggestion

In recent years, people who suffered from AH generally showed significantly impaired performance in both attention and memory domains involving reduced selective attention, sustained attention, retrospective memory, and prospective memory ability, while its effect on divided attention is controversial [9-14]. The study that supported divided attention was affected during AH suggested that a lack of attentional resources when responding to multiple stimuli might be the underlying mechanism of the deficit performance during AH [5].

However, the utility of distinct methodologies had different limitations that may affect the research results and lead to inconsistent findings. Among them, three study distinctions might be the key contributors: laboratory studies vs. naturalistic studies, within-subject design vs. between-subject design, and student sample vs. non-student sample. Firstly, naturalistic study design gained great popularity in recent years as researchers believed the expectancy effect was eliminated and the ecological validity was improved using this design by allowing participants to consume alcoholic drinks at their typical drinking level in reality circumstances. However, the types of alcohol and time of drinking were not well controlled which might be confounding factors underlying the results [7, 11]. For laboratory study design, even though the expectancy effect was thought to be the main methodological drawback, it could be reduced by a double-blind experimental design. In addition, a recent study demonstrated that attention and memory performances during AH state were not differentially influenced by expectancy effects [15]. The experimenters conducted a naturalistic study and divided participants into two groups: the expectancy group (people were told that the aim of the study was to test the effects of AH) and the control group (people were informed that the aim of the study was to examine the effects of the distinct time period during one day). They found no significant differences in the cognitive behavior observed between the two groups during the AH condition. But for the exception of hangover-resistant subjects [16], they should be carefully treated in laboratory study design because they may not experience any adverse AH symptoms after sufficient alcohol consumption to induce the AH within the ethical boundary. Therefore, a well-controlled double-blind experimental study actively asking the AH symptoms to exclude or distinguish the hangover-resistant individuals would also provide reliable results. For naturalistic studies, the drinking time and types of alcoholic drinks should be recorded or even controlled

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(like in semi-naturalistic studies) to remove these confounding factors. In conclusion, both laboratory and naturalistic study designs could be valid and reliable with careful study restrictions.

Moreover, in laboratory studies, within-subject and between-subject designs may also play key roles in the research results. For between-subject design, as different groups of people were recruited in two conditions, individual variability was the major methodological flaw. To improve it, a large sample size and the control over intelligence scores and group age range are needed to reduce the effects of individual differences. For within-subject design, as the same group of participants was tested two times under distinct alcohol states after appropriate time intervals, order effects should be carefully avoided to enhance the validity. For example, counterbalancing is a useful solution to reduce the order effects by asking one group of participants to finish the tasks during the AH state first, while requiring the corresponding group of participants to go through the task during the non-AH state first. In addition, the time interval between the two experiments should be the same for every subject and be sufficient for AH symptoms to completely disappear in non-AH state.

Last but not least, the identities of the experimental subjects are also important for researches on AH effects. The majority of studies recruited student samples as they are the most accessible target for research teams [10], while the generalization of these researches was affected as student groups are restricted to high intelligence, young age, and high education level samples. To further study the alcohol hangover effects on cognitive functions, the samples with a wide range of age groups (e.g. ranging from 18 to 60 years old) and various social identities (e.g. caretakers, gardeners, teachers, engineers, and social media influencers) should be examined to investigate whether the results are consistent and what the contributors are for these differences.

6. Conclusion

To sum up, for the attention domain, the alcohol hangover state had constant adverse effects on the performances of selective attention and sustained attention tasks, while the performances of divided attention tasks were conflicting. The attentional allocation processes were affected by the AH state and the depleted attentional resource in individual tasks was thought to be the underlying mechanism of the impaired divided attention performance observed in several researches. For the memory domain, during the retrospective memory process, although the encoding phase was suggested to play a more important role in both long-term and short-term memory deficits, the hypothesis is not fully convincing as the function of the retrieval phase has not been separately examined. Besides, studies also illustrated impaired prospective memory function during the AH state, which provided insights into the planning and executive function problems that occurred among people after AH. Last but not least, several changes could be made in the future to reduce the methodological limitations in AH studies.

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